MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EPM4066 – ROBOTICS AND AUTOMATION

(ME)

6 MARCH 2019
9:00am - 11:00am
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 6 pages including cover page and appendix with 4 Questions only. DH-parameter procedures are included in Appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Define the term of "Kinematics" and "DOF".

[4 marks]

(b) For the 3-DOF (RRP) manipulator arm shown in Fig. Q1, assume that the last two links are vertically aligned when in the home position.

(i) Determine the frame assignment.

[6 marks]

(ii) Determine the joint link parameter.

[5 marks]

(iii) Obtain the overall homogeneous transformation matrix.

[10 marks]

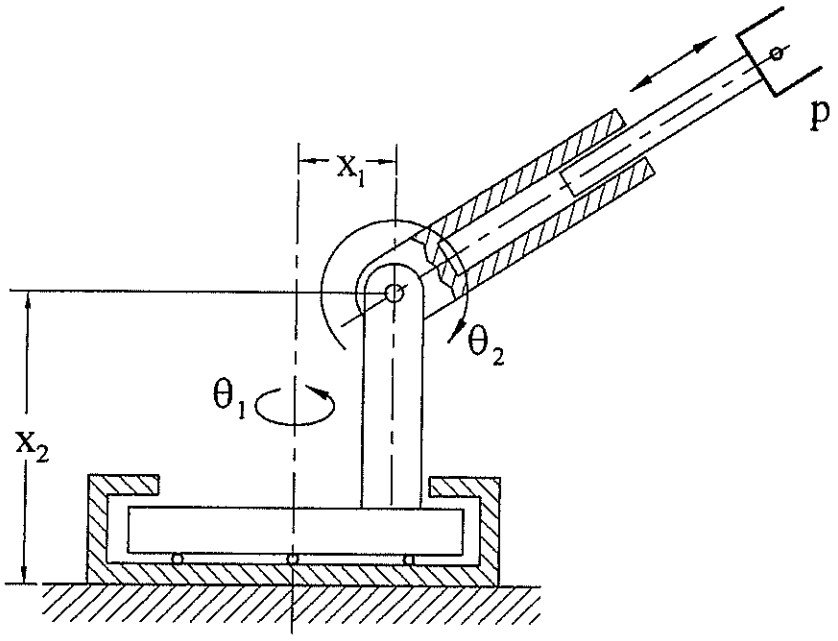

Fig. Q1

Continued...

Question 2

(a) Calculate the gripper force based on the following data:

Mass of part is 2.5 kg.
The part is grasped 60 cm from its CG.
The width of jaws is 10 cm.
The part is 5 cm thick.
The coefficient of friction between the part and gripper is 0.85.
A safety factor of 2 must be included.
The acceleration due to gravity is 9.8 m/s2

[5 marks]

(b) Draw a trajectory of simple pick and place work with an obstacle.

[4 marks]

(c) Define three distinct training activities should be implemented by every industrial plant that considers introducing robots to the production process.

[6 marks]

(d) The waist of a six-axis robot is to go from initial angle of 25° to an end position of 61° in 6 seconds. By using a third-order polynomial in joint-space, calculate and sketch the trajectories (free hands) of the joint angle, velocity, and acceleration at the times of 1, 2, 3, 4 and 5 seconds. Assume the robot starts at rest and all joints stop at end point.

[10 marks]

Continued...

Question 3

(a) What are the five characteristics that all end-of-arm tooling must satisfy?

[5 marks]

(b) If you have the choice between giving a robot speech interpretation abilities or vision interpretation abilities, which will you choose and why?

[4 marks]

(c) Consider the link-coordinate diagram of a 3-axis planar articulated robot. The arm matrix for this robot is given by:

$$T_{base}^{tool} = T_0^1 T_1^2 T_2^3$$

$$= \begin{bmatrix} C_1 & -S_1 & 0 & a_1C_1 \\ S_1 & C_1 & 0 & a_1S_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C_3 & -S_3 & 0 & 0 \\ S_3 & C_3 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Find:

(i) The manipulator Jacobian matrix, $J(q)$.

[9 marks]

(ii) An end-of-arm force and moment vector, F^{tool}, that induces joint torques of $[1, 1, 0]^T$.

[7 marks]

Continued...

Question 4

(a) Briefly explain the following types of productions.
(i) Batch Production
(ii) Mass Production

[4 marks]

(b) Plant layout refers to the arrangement of physical facilities in a production plant. Explain briefly the three principal types of plant layout.

[6 marks]

(c) A new production machine costs RM90,000 and is expected to generate revenues of RM50,000 per year for 7 years. It will cost RM35,000 per year to operate the machine. At the end of 7 years, the machine will be scrapped at zero salvage value. Determine the payback period for this investment.

[5 marks]

(d) The cost of the raw material for a certain part is RM200. The part is processed through 25 processing steps in the plant and the manufacturing lead time is 20 weeks. The production time per processing step is 1 hour and the machine and labour rate is RM20/h. Inspection, material handling, and related costs average RM20 per processing step by the time the part is finished. The interest rate 'i' used by the company is 20% and the storage rate,'s' is 15%. Determine the cost per part and the holding cost.

[10 marks]

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Appendix

DH-Parameters for frame assignment estimation of robot

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set k =1.
3. Align z^k with the axis of joint k + 1.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set k =1.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

End of Paper